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EVALUATION OF THERMAL STABILITY IMPROVING ADDITIVES FOR JET FUEL IN BOTH LAMINAR AND TURBULENT FLOW TEST UNITS

John E. Colbert & Clarence J. Nowack
U.S. Naval Air Systems Command
Patuxent River, MD
27 September 2000

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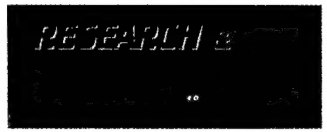
BACKGROUND



(1) New test units are being developed to quantify deposits as an improvement over the JFTOT.

(2) These units (quantitative), as stand now, are very useful in evaluating the effects of additives on a laboratory scale.

(3) Scientific community questions the validity of laminar results when aircraft fuel systems are in the turbulent flow regime.

(4) The purpose of this test program is evaluate the effectiveness of additives in two (2) different test devices - one laminar and the other in the turbulent flow regime.

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OBJECTIVES

RESEARCH

(1) Determine the sensitivity of two (2) laboratory test units to measure the effectiveness of three (3) different additives in three (3) different types of JP-5.

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EXPERIMENTAL

1. Test Unit Specifications:

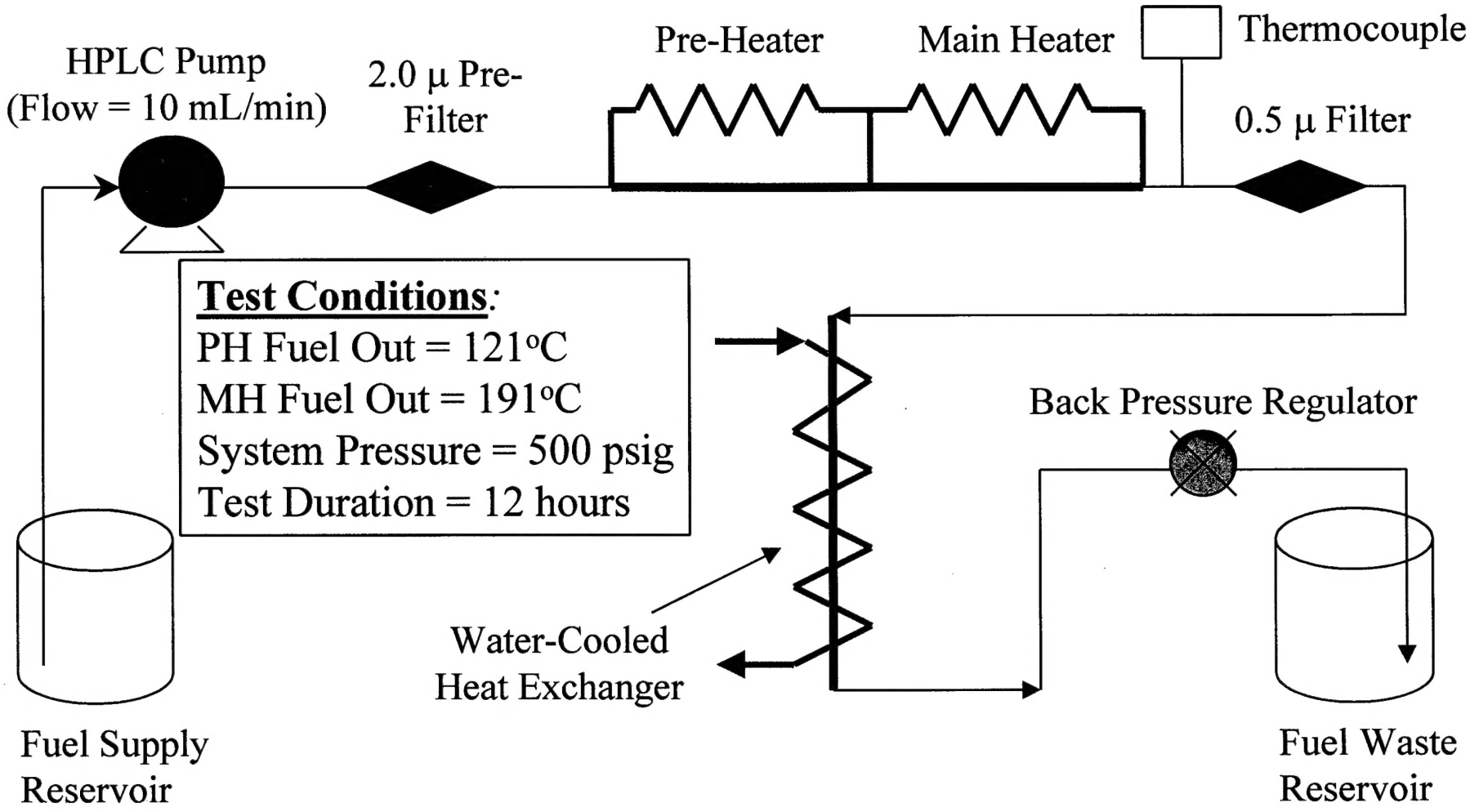
	SS Tube Dimensions								
Test Unit	ID	Effective Heated Length	Flowrate	Pre-Heater Exit Temp	Main Heater Exit Temp	Re#	System Pressure	Test Duration	Tube Exit Filter
	(inches)	(inches)	(mL/min)	(^{0}C)	(^{0}C)	(unitless)	(psig)	(hours)	(μ)
Laminar (STR)	0.103 (0.2616 cm)	5 (12.7 cm)	10	121	191	200	500	12	0.5
Turbulent (HiReTS)	0.01 (0.0254 cm)	5.3125 (13.493 cm)	35	N/A	290	13,000	500	Variable[(1)]	None

NOTES:

(1) Run HiReTS until a HiReTS No. $\geq$ 1000 is achieved (capillary failure condition).

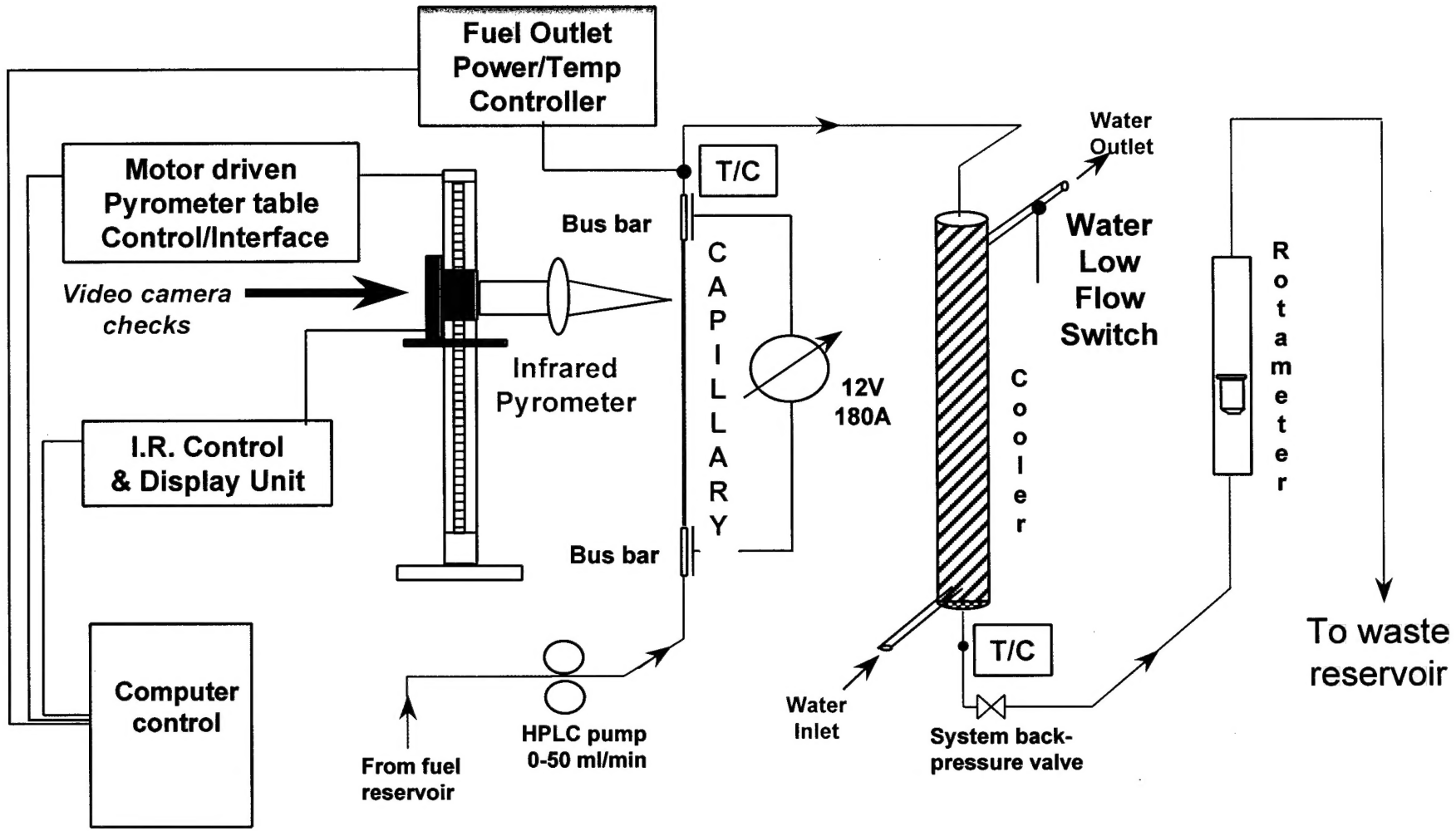
EXPERIMENTAL (Cont.)

2a. Test Units (Laminar) - Single Tube Reactor:



EXPERIMENTAL (Cont.)

2b. Test Units (Turbulent) - HiReTS:



EXPERIMENTAL (Cont.)

3. **Fuels (3 JP-5s):**

a. ***Red Hill Tank 4*** - shipped from Hawaii and refined by ARCO. An unusual JP-5 due to nitrogen content of 60 ppb which caused the JFTOT to fail with a BPT = 255°C.

b. ***Tank 17/19*** - a typical JP-5 with a JFTOT BPT = 272°C originating from U.S. Navy facility at Trenton, NJ. Subsequently shipped to Patuxent River, MD for in-house testing.

c. ***Tank 20/22*** - A JP-5 containing 50 ppb copper, which is typical of a JP-5 stored on air-capable ships containing copper piping. JFTOT BPT = 265°C.

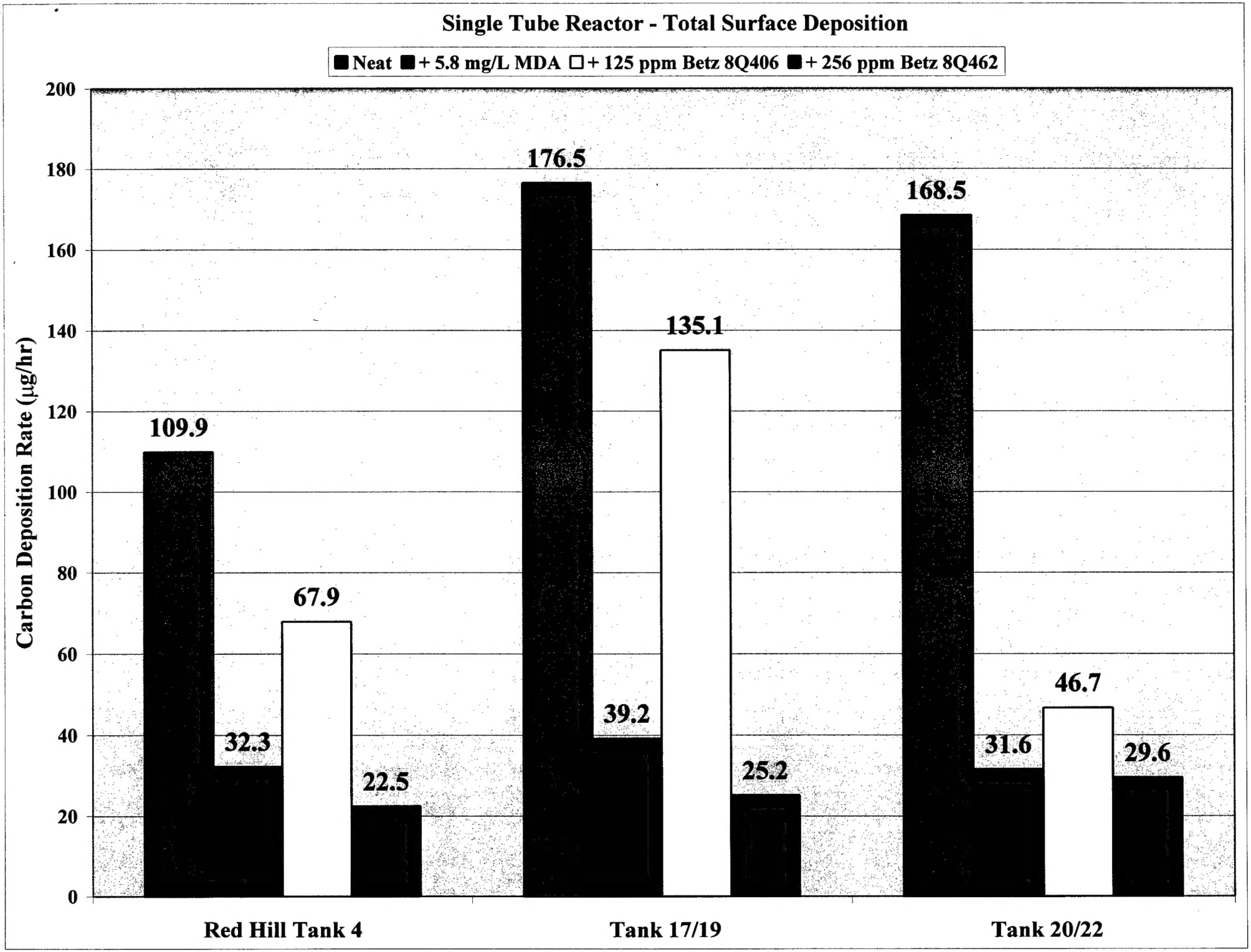
EXPERIMENTAL (Cont.)

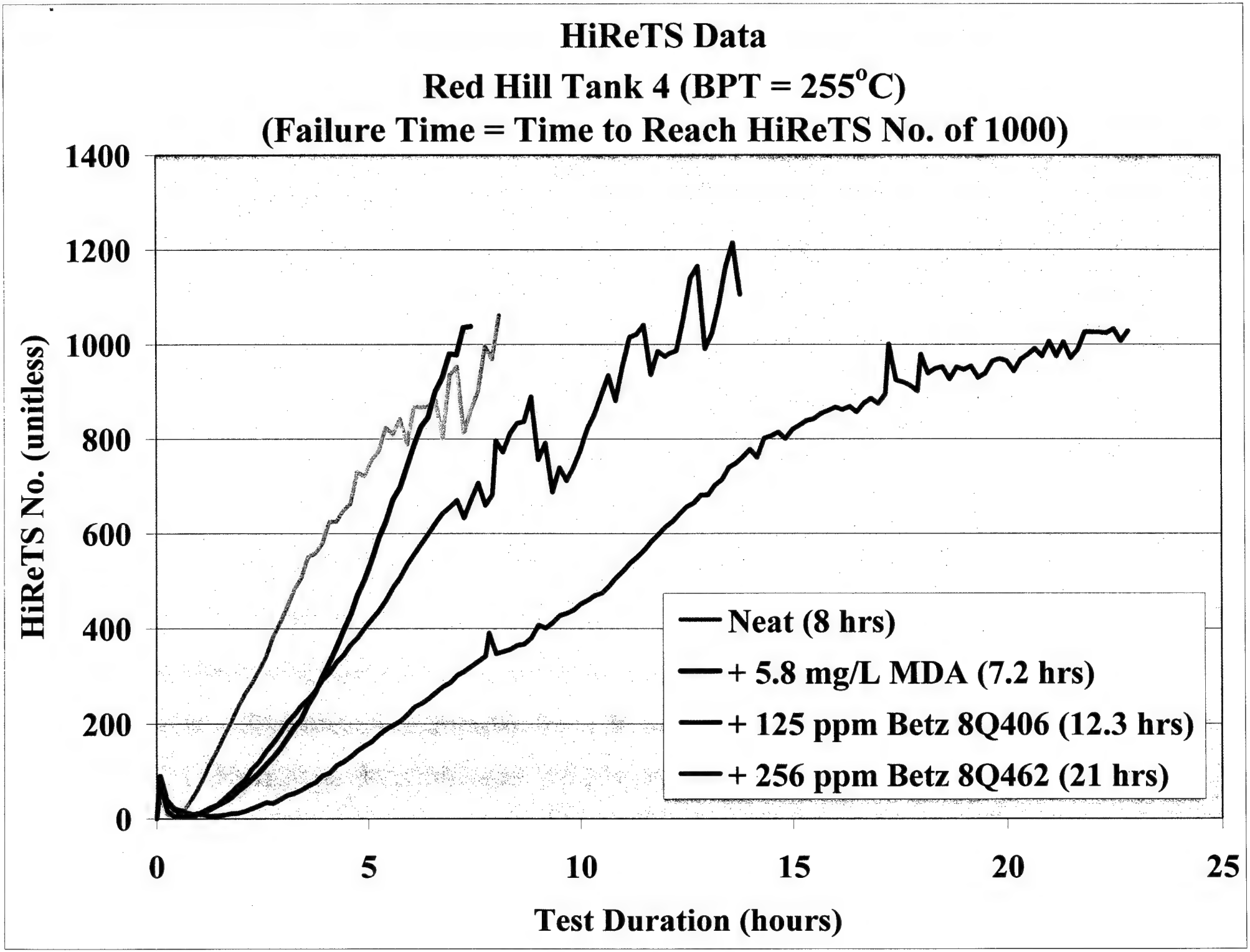
4. Thermal Stability Improving Additives (TSIAs):

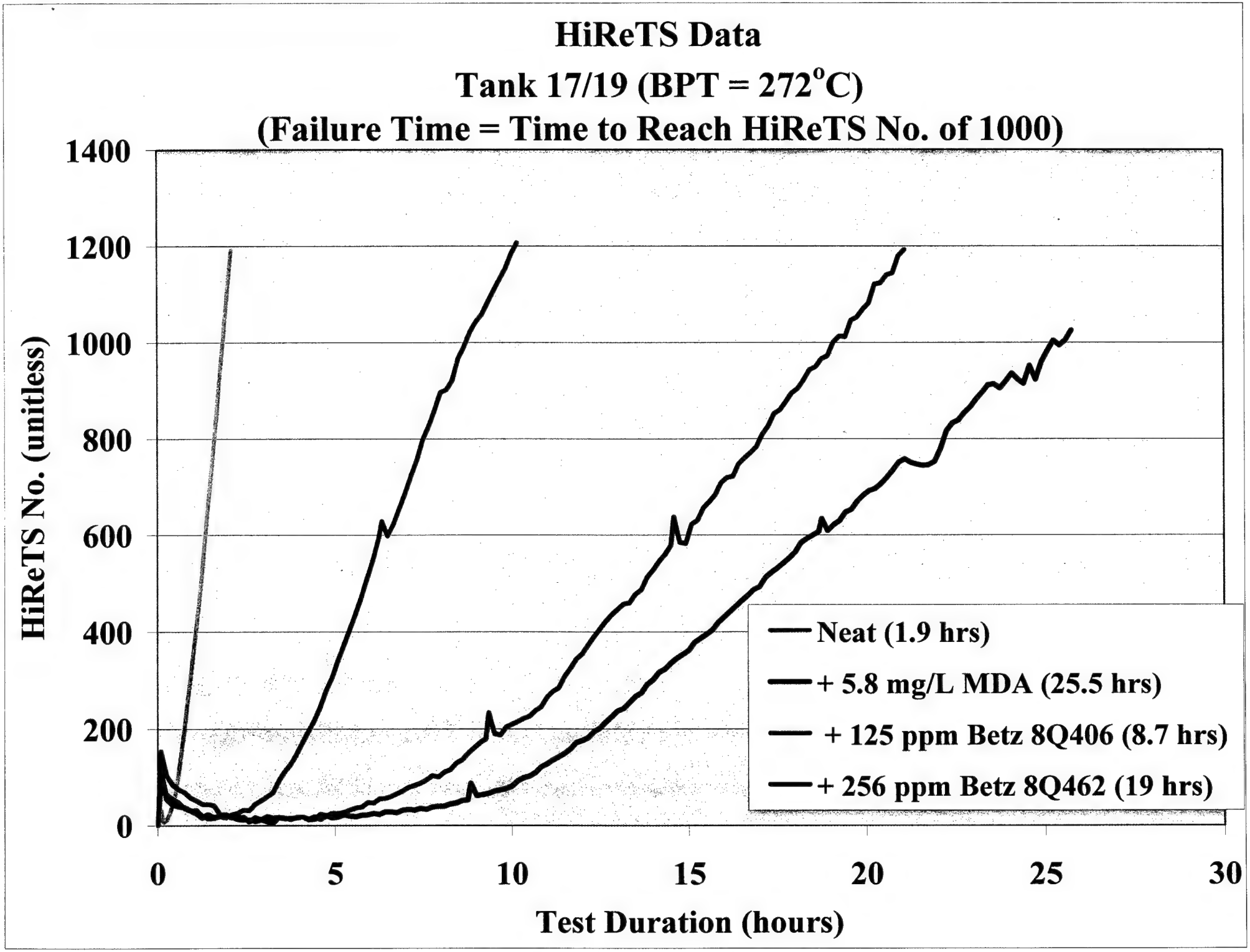
a. ***MDA*** - N,N-disalicylidene 1,2-propane diamine. This is a chelate type of compound approved for use in jet fuel used to suppress the catalytic activity of soluble copper. The maximum allowable dosage is 5.8 mg/L.

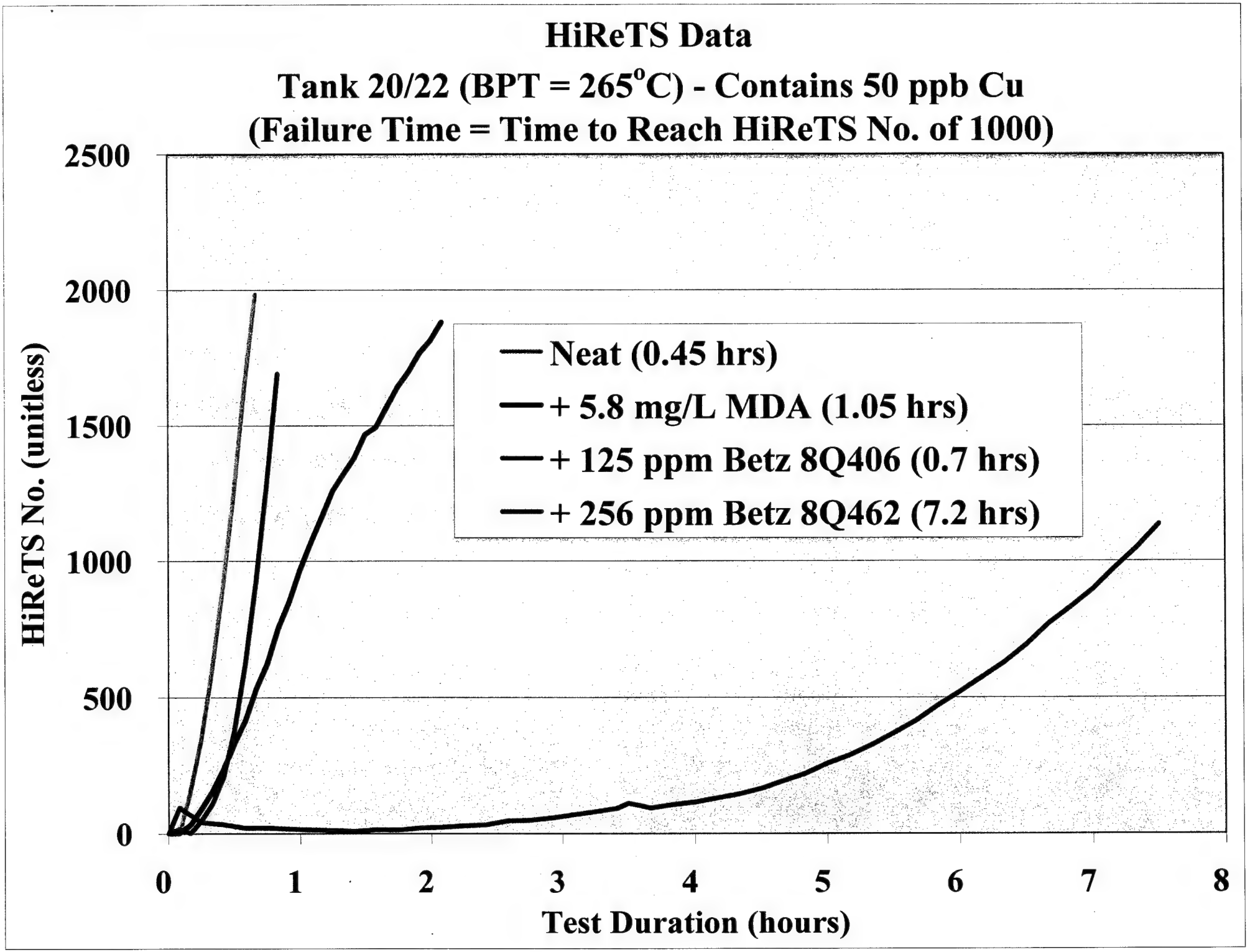
b. ***Betz 8Q406*** - a proprietary formulation consisting of a detergent/dispersant and a butylated hydroxyltoluene contained in a hydrocarbon carrier. The recommended dosage is 125 ppm (v/v).

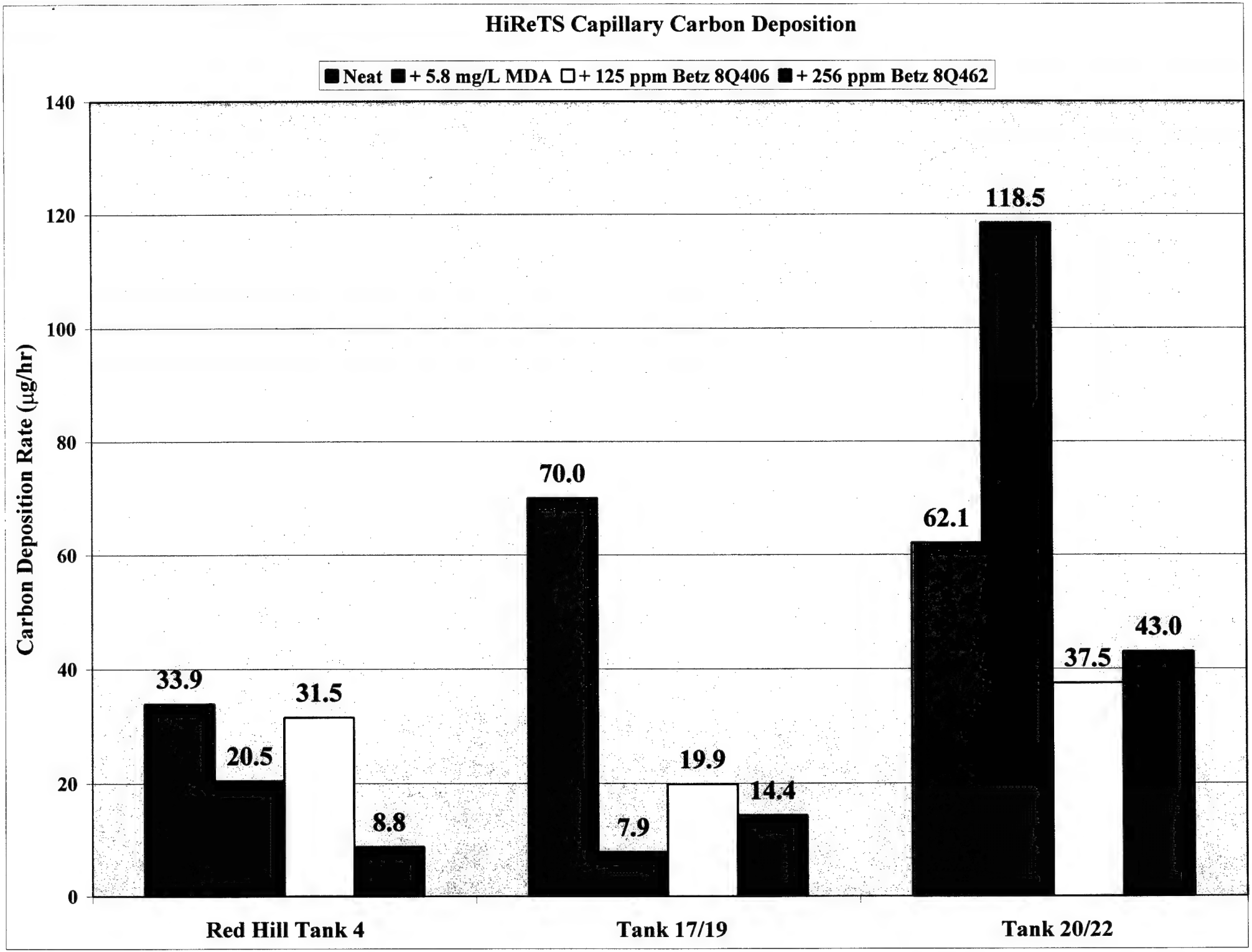
c. ***Betz 8Q462*** - this additive is the same as 8Q406 except it contains 2 mg/L MDA. It is used at a concentration of 256 ppm (v/v).

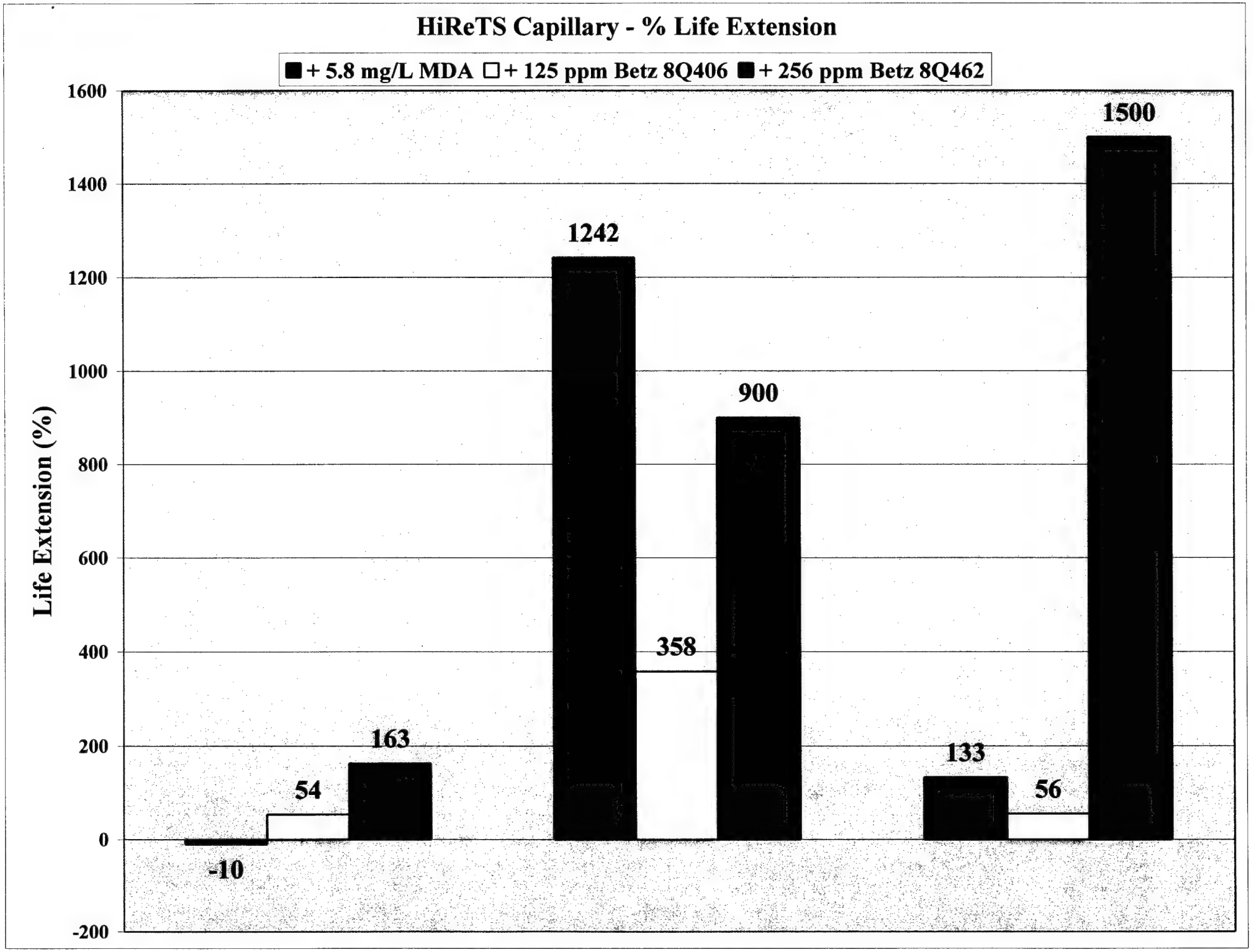

Single Tube Reactor - Total Surface Deposition
Neat
+ 5.8 mg/L MDA
+ 125 ppm Betz 8Q406
+ 256 ppm Betz 8Q462
Carbon Deposition Rate (µg/hr)
200
180
160
140
120
100
80
60
40
20
0
109.9
32.3
67.9
22.5
176.5
39.2
135.1
25.2
168.5
31.6
46.7
29.6
Red Hill Tank 4
Tank 17/19
Tank 20/22

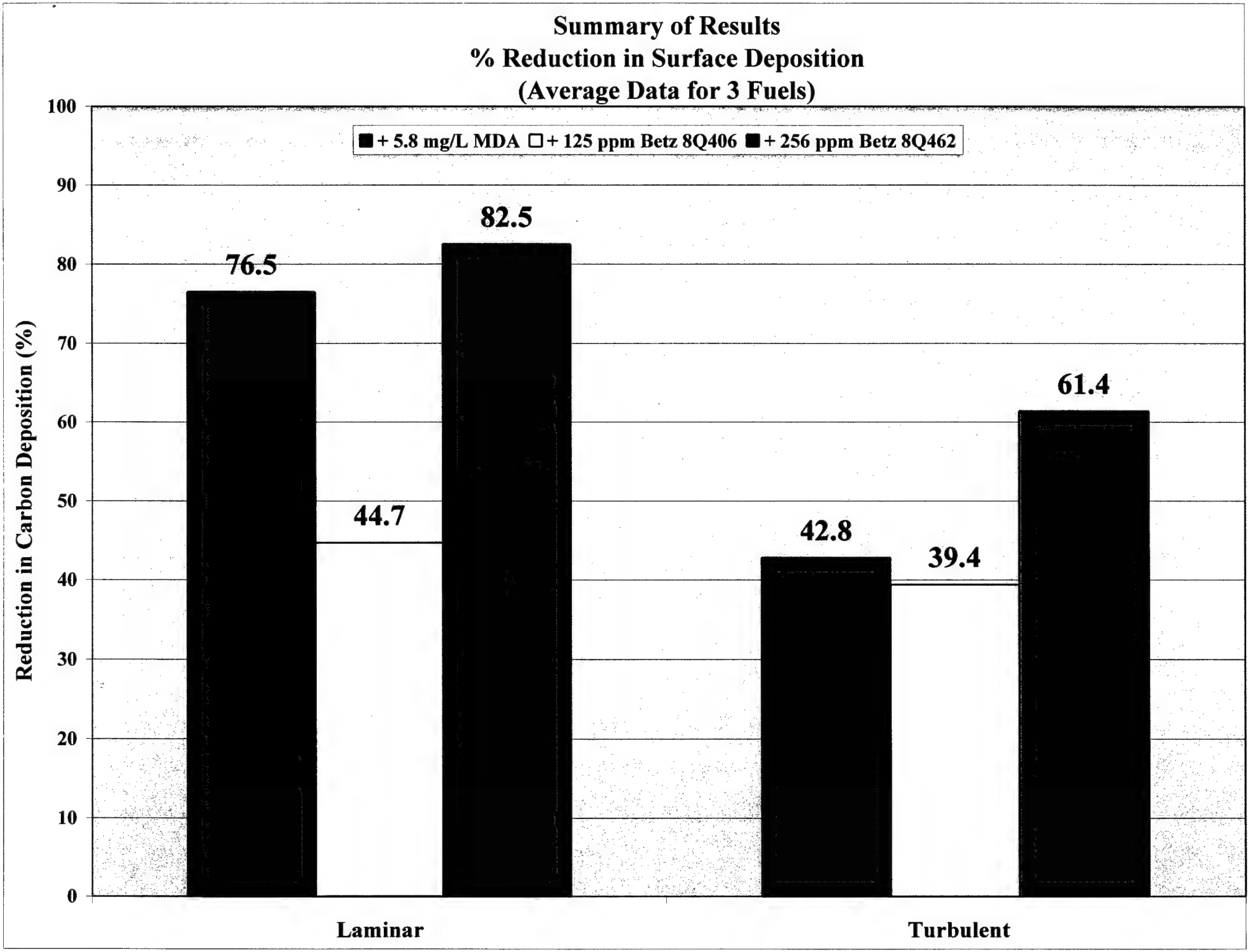

HiReTS Data
Red Hill Tank 4 (BPT = 255°C)
(Failure Time = Time to Reach HiReTS No. of 1000)
HiReTS No. (unitless)
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
Test Duration (hours)
Neat (8 hrs)
+ 5.8 mg/L MDA (7.2 hrs)
+ 125 ppm Betz 8Q406 (12.3 hrs)
+ 256 ppm Betz 8Q462 (21 hrs)


HiReTS Data
Tank 17/19 (BPT = 272°C)
(Failure Time = Time to Reach HiReTS No. of 1000)
HiReTS No. (unitless)
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
Test Duration (hours)
Neat (1.9 hrs)
+ 5.8 mg/L MDA (25.5 hrs)
+ 125 ppm Betz 8Q406 (8.7 hrs)
+ 256 ppm Betz 8Q462 (19 hrs)


HiReTS Data
Tank 20/22 (BPT = 265°C) - Contains 50 ppb Cu
(Failure Time = Time to Reach HiReTS No. of 1000)
HiReTS No. (unitless)
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
Test Duration (hours)
Neat (0.45 hrs)
+ 5.8 mg/L MDA (1.05 hrs)
+ 125 ppm Betz 8Q406 (0.7 hrs)
+ 256 ppm Betz 8Q462 (7.2 hrs)


HiReTS Capillary Carbon Deposition
Neat
+ 5.8 mg/L MDA
+ 125 ppm Betz 8Q406
+ 256 ppm Betz 8Q462
Carbon Deposition Rate (µg/hr)
140
120
100
80
60
40
20
0
33.9
20.5
31.5
8.8
70.0
7.9
19.9
14.4
62.1
118.5
37.5
43.0
Red Hill Tank 4
Tank 17/19
Tank 20/22


HiReTS Capillary - % Life Extension
+ 5.8 mg/L MDA
+ 125 ppm Betz 8Q406
+ 256 ppm Betz 8Q462
Life Extension (%)
1600
1400
1200
1000
800
600
400
200
0
-200
-10
54
163
1242
358
900
133
56
1500


Summary of Results
% Reduction in Surface Deposition
(Average Data for 3 Fuels)
+ 5.8 mg/L MDA
+ 125 ppm Betz 8Q406
+ 256 ppm Betz 8Q462
Reduction in Carbon Deposition (%)
100
90
80
70
60
50
40
30
20
10
0
76.5
44.7
82.5
42.8
39.4
61.4
Laminar
Turbulent

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CONCLUSIONS

- All three (3) TSIAs reduce the amount of thermal deposits, measured via carbon burnoff, in both laminar and turbulent test units for the three (3) different base fuels tested.

- For the laminar test unit, Betz 8Q462 shows better deposit inhibition than MDA by a narrow margin.

- Therefore, MDA shows a synergistic effect when added to the Betz 8Q406 (to produce Betz 8Q462) in the laminar unit.

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CONCLUSIONS (Cont.)

- The turbulent unit is sensitive to differences in fuel chemistry, possibly due to the higher operating temperatures and/or the HiReTS capillary dimensions (viz., inside diameter).

- The higher operating temperatures of the turbulent unit may be unrealistic (i.e., too severe) for evaluating additives.

- Nevertheless, Betz 8Q462 appeared to be the most effective additive overall in the HiReTS.

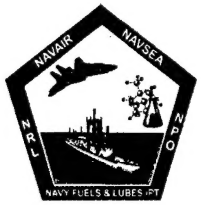
RECOMMENDATIONS

- For research purposes, the following modifications should be considered to make the HiReTS better-suited for evaluating fuels and additives:

  - Incorporate a pre-heater

  - Operate at a lower capillary exit temperature

  - Run the test for an extended duration until a capillary failure condition is achieved while minimizing the test duration and fuel consumption



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RECOMMENDATIONS (Cont.)

- For the HiReTS, scan a larger length of the capillary to include SEC 2 and SEC 3 to get a better indication of true deposition rate.

- Use the HiReTS No. as an indication of deposit level and/or rate. Also, reduce the test duration until a HiReTS No. of 500 is achieved and measure the associated deposition rate.